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Forest Health Protection
Pacific Southwest Region

Date: June 22, 2005
File Code: 3420

To: District Ranger, Warner Mountain Ranger District, Modoc National Forest

Subject: Evaluation of Blue Lake and Cedar Pass Campgrounds (FHP Report NE05-04)

At the request of Dan Hubbard, Silviculturist, Warner Mountain Ranger District, Modoc National Forest (MNF), Danny Cluck, Forest Health Protection (FHP) Entomologist, and Bill Woodruff, FHP Plant Pathologist, conducted a field evaluation of the Blue Lake and Cedar Pass Campgrounds on May 26, 2005. The objective of the visit was to evaluate the current level of bark beetle related mortality, identify and discuss hazard tree characteristics including root diseases and bole decays and provide recommendations as appropriate. Dan Hubbard, Anne Mileck, Monte White, Bill Schoeppach, Terry Reedy, Jessie Berner, Louis Haynes and Dave LeBlanc from the MNF and Joel Egan and Steven McFarland from FHP accompanied us in the field.

Background

Blue Lake Campground is located in the southeast corner of the Modoc National Forest on the Warner Mountain RD about 12 miles southeast of Likely, CA. The elevation of the site is approximately 6,100 feet with precipitation averaging 16-20 inches per year. The campground consists of a mix of ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor*), and scattered western juniper (*Juniperus occidentalis*). Trees range in size from saplings to large diameter (30"+) stems.

Cedar Pass Campground is located in a small canyon off Highway 299 about 12 miles west of

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Cedarville, CA (Warner Mountain RD, Modoc NF). The elevation of the site is approximately 5,800 feet with precipitation averaging 20-25 inches per year. White fir is the dominant tree species in the campground followed by ponderosa pine. Trees range from saplings to large diameter (30" +) stems. Riparian deciduous hardwoods, consisting mostly of willow (*Salix sp.*) and black cottonwood (*Populus trichocarpa*) are found along the creek that runs through the campground.

Management activities in both campgrounds have been limited to the removal of dead or dying hazard trees.

Observations

Blue Lake Campground

Western pine beetle (*Dendroctonus brevicomis*) is attacking and killing up to 20 % of the ponderosa pines within the campground as evidenced by fading crowns, pitch tubes, frass and/or boring dust, and woodpecker foraging of beetle larvae (bark flaking/removal). Bark beetle killed and green infested trees range in size from 6" to 30+" dbh. The green infested trees were attacked in the late summer to early fall of last year and contain many western pine beetle larvae. All dead and currently infested trees have been marked for removal.

Bark flaking caused by woodpecker foraging of western pine beetle larvae is extensive on many trees with most of the bark removed from infested portions of the boles. It is likely that this foraging is significantly reducing brood success within the campground. Interestingly, there are a few trees where woodpeckers have flaked the outermost layers of bark off of un-infested trees. This type of bark flaking is distinctive from the bark flaking occurring on infested trees. These trees are not marked for removal.

One ponderosa pine had the top of its crown fading without signs of western pine beetle attack on the bole. Attacks by the pine engraver beetle (*Ips pini*) are suspected as the cause. A few trees have many cream-colored pitch tubes from unsuccessful western pine beetle attacks and red pitch tubes from red turpentine beetle (*Dendroctonus valens*) attacks on the mid and lower boles, respectively. Thus far, these trees have not succumbed to the western pine beetle attacks although some of the red turpentine beetle attacks may be successful.

Fir engraver beetle (*Scolytus ventralis*) is attacking and killing approximately 5% of the white fir in the stand. Some attacks are resulting in top kill only. Approximately 20 % of the live white firs have older dead tops that were likely attacked and killed by fir engraver beetles during the last drought period (1987-1992).

No signs or symptoms of root disease were observed in either white fir or ponderosa pine. Although active root disease centers were not observed during this evaluation, black stain root disease, caused by *Leptographium wageneri*, and annosus root disease were identified during a 1983 FHP field evaluation of the Blue Lake campground (FHP Report #84-17). Based on these prior observations, it is likely that root disease is still active and increasing conifer susceptibility to bark beetle attack.

Cedar Pass Campground

Several biotic agents such as dwarf mistletoes, root diseases, stem decays, and engraver beetles are affecting white fir throughout the campground. Many of the older white fir have unhealthy crowns with dead tops, dead limbs and thin foliage. In addition, extensive root and bole decay was observed in many stumps of recently felled dead trees and some standing live trees.

Dwarf mistletoe (*Arceuthobium abietinum* f.sp. *concoloris*) has infected nearly every white fir tree within the campground and has caused considerable branch dieback and bole and limb swellings.

Fruiting bodies, or conks, of *Heterobasidion annosum*, the causal agent of annosus root disease were observed in several decaying white fir stumps. Laminated decay, another sign of annosus root rot, was observed in the roots of a large diameter white fir that failed over the winter. Prior FHP evaluations in 1984 and 1994 (FHP Report #84-17 and FHP Report #NE95-03) also documented the presence of annosus root disease within the Cedar Pass campground.

Fir engraver beetle (*Scolytus ventralis)* is causing top-kill or whole tree mortality in approximately 5% of the white fir in the campground. Most trees that have been felled over the last few years reveal galleries of the fir engraver beetle.

Observations Common to Both Campgrounds

There is evidence of mechanical injury on a few trees resulting from campers hammering nails into trees and cutting into trees with hatchets or saws.

High foot and vehicle traffic is occurring in and around the campsites. This is evidenced by the lack of vegetation in many areas and is likely resulting in highly compacted soils around tree roots in addition to direct root damage. Compaction may be limited in the Blue Lake Campground due to rocky soils.

Trees with bole defects resulting from sucker limbs, basal wounds, or fire scars and have been marked for removal as hazards in both campgrounds.

Discussion and Recommendations

Trees in the Blue Lake and Cedar Pass campgrounds, similar to most forested campgrounds, are exposed to additional stress factors that can compromise their health and vigor. Firewood collecting sometimes leads to tree wounding from hatchets and saws, foot and vehicle traffic from campers can result in increased soil compaction and root damage, and the desire for screening between campsites can result in overstocking of understory trees.

Trees that succumb to bark beetle attacks are typically predisposed by factors that compromise tree health and vigor. In the Blue Lake campground, high stand density, root disease and prolonged drought are the main factors associated with tree mortality. In the Cedar Pass

campground, high stand density, prolonged drought, dwarf mistletoe and annosus root disease are all contributing factors in the decline of tree health and the observed white fir mortality. Using weather data from Cedarville as a local indicator, precipitation in the Warner Mountains was below normal from 1999-2004 (Table 1).

Table 1. Cedarville Annual Precipitation 1999-2004.

YEAR	Total Precipitation (in)	% Of Average (12.96")
1999	9.63	74%
2000	8.25	64%
2001	9.62	74%
2002	7.76	60%
2003	12.5	96%
2004	11.76	91%

The long-term average annual precipitation of 16-25" for these sites is below what is generally required to sustain white fir over a generation. Therefore, even with lower stocking levels, white fir growing on these sites is at a higher risk for fir engraver beetle related mortality, especially top-kill. High stand densities combined with the last prolonged drought (1987-1992) resulted in elevated levels of white fir mortality throughout the Modoc National Forest as documented in previous FHP evaluations (Schultz 1994) and aerial surveys. During this time, the areas with the highest white fir mortality were those with less than 30" average annual precipitation.

White fir with a minimal amount of top kill, as a result of fir engraver attacks, should survive. Based on past observations and the results of an administrative study of top-killed white fir in northeastern California (Smith and Peterson 2000), trees with minimal top kill generally survive and many grow new leaders. However, depending on continued drought conditions and additional fir engraver attacks below the top killed portion of crowns, whole tree mortality may occur.

Ponderosa pine and white fir in both the Blue Lake and Cedar Pass campgrounds will remain susceptible to high levels of mortality due to the overstocked condition of the stands, current bark beetle activity, root disease and prolonged drought. Additional tree mortality should be expected this year. Trees will fade this spring and summer as a result of successful bark beetle attacks during 2004 and some additional ponderosa pine may fade by late summer/early fall from attacks sustained during the first flight of western pine beetle sometime in late June 2005.

Blue Lake Campground

Based on recent FHP observations (FHP Report NE04-03) and observations by District personnel, current bark beetle caused mortality of ponderosa pine in the Warner Mountains began approximately three years ago and has since increased dramatically over the entire California portion of the mountain range. Bark beetle caused mortality is also increasing throughout the rest of northeastern California, due in part, to the past six years of below normal precipitation.

Some questions were asked regarding the need to remove western pine beetle infested ponderosa pine before beetle emergence in order to reduce the chance of having adjacent, un-infested, trees attacked. While this may be a valid management option for some other bark beetle species, such as mountain pine beetle (*Dendroctonus ponderosae*) in lodgepole pine (*Pinus contorta*) or Jeffrey pine beetle (*Dendroctonus jeffreyi*) in Jeffrey pine (*Pinus jeffreyi*), where beetles emerge from one tree and typically attack adjacent trees, observations of group kill dynamics do not suggest that western pine beetles consistently attack nearby pines upon emergence. Rather, the specific location of new group kills is unpredictable as beetles may fly for some unknown distance and direction before attacking a new host tree. Furthermore, previous management activities that have attempted to control or suppress western pine beetle populations in ponderosa pine stands have failed. Because adult beetles can fly many miles and produce many offspring, effective suppression methods require the location (spotting) and treatment of all, or nearly all, infested trees over extensive areas in a short period of time. Also, these projects have failed because the basic underlying cause for the population outbreak, the abundance of stressed trees, has not changed. Typically, if a habitat favorable to high beetle populations persists, control or suppression by whatever means will fail to significantly reduce tree mortality.

Preventative spraying with insecticides of un-infested high value trees can be an effective treatment option to prevent further bark beetle caused mortality. Although not a long-term solution, spraying tree boles with insecticides such as permethrin or carbaryl will provide one to two years of protection from bark beetle attacks. Consideration needs to be given to the choice of insecticide since the campground is in close proximity to the lake. Permethrin cannot be sprayed within 25 feet of water and the buffer for spraying carbaryl near water is a minimum of 100 feet. Spray height on individual trees, which affects drift, and potential for runoff must be accounted for in determining safe distances from water. Permethrin has low toxicity to birds and mammals but is extremely toxic to some fish and aquatic arthropods and is highly toxic to bees. Carbaryl is considered more toxic than permethrin to bees and is extremely toxic to aquatic invertebrates. All non-infested trees greater than 6" dbh within the campground would need to be treated for complete protection. District personnel may choose to be more selective in treatments, possibly only spraying larger diameter trees or specific trees in and around campsites.

Cedar Pass Campground

Root decay caused primarily by *H. annosum* and potential decay at dwarf mistletoe bole swellings, all in white fir, are the most serious conditions identified in the Cedar Pass campground. Many trees have been felled within the past few years that had previously succumbed to some combination of root disease, dwarf mistletoe and fir engraver beetle attacks. Some of these trees were likely hazardous before they died. With this many trees affected in a campground, it is critical that the remaining live trees are evaluated and potential hazards identified. Treatment for a hazard tree (a defective tree located where it could kill or injure people or damage property if it fell) is to remove the tree or to keep people and property away from the tree. The most effective ways to keep people away from hazard trees are to move the facility (picnic table, campsite, toilet, etc) or construct barriers around the trees.

Identifying hazards by signing does not relieve the Forest Service from liability for injury or

damage caused by known tree hazards. Liability can only be eliminated by closing hazardous areas or removing the hazard. Liability can be minimized by implementing an on-going tree hazard identification and treatment program for recreation areas. This program would involve periodically examining trees in recreation areas, removing or mitigating those deemed hazards, and monitoring questionable trees over time.

Many trees within the campground have large bole and limb swellings caused by fir dwarf mistletoe. White fir within the camping area that exhibit bole swellings should be carefully inspected for loose bark and stem decay, as these swellings can be an entry court for decay fungi. If decay is present, the tree should be considered a hazard and removed. Trees with bole swellings that do not reveal decay should be monitored closely. For trees with branch swelling and brooms, depending on the degree of symptoms, consideration should be given to tree removal or, at a minimum, selective pruning within the crown to remove the dead or diseased limbs that could snap off and strike campers or vehicles. Depending on the level of dwarf mistletoe infection, removal of infected limbs can improve the health and vigor of the tree as long as at least 50% of the original live crown remains after treatment.

Soil compaction within the campground may be partially responsible for predisposing the fir trees to root diseases and bark beetle attacks. Compacted soils tend to suffocate roots, limiting the available oxygen required for root growth and survival. Damaged and unhealthy roots cannot provide the upper portions of the tree with the water and nutrients needed to maintain its natural defenses. Root damage is a long-term problem that may not reveal itself until several years after the damage has occurred. In order to minimize future soil compaction and root damage, campers should be confined to specific travel corridors from campsites to restrooms, water sources, and specific recreation areas. It is especially important to divert and limit foot and vehicle travel as much as possible from the root zones of trees.

Thinning recommendations for Blue Lake and Cedar Pass

Develop long-term management plans that include stand management objectives for the campgrounds. Stands within both campgrounds would benefit from thinning. When thinning trees in the campgrounds, it is recommended to select for a residual mix of species with priorities given to species other than white fir. In addition, when selecting trees for removal, preference should be given to trees infected with dwarf mistletoe, root disease, trees infested with bark beetles and trees with extensive human caused injuries. For root diseases it is reasonable to use the condition of the crown as an indicator of advanced decay. Although not always caused by root decay, a thin crown does indicate poor tree vigor. A tree with reduced photosynthetic capability is not able to maintain healthy roots as well as a tree with a full and healthy crown. In the presence of root disease, unhealthy roots will likely be overcome with decay faster than vigorously growing roots. The thinner the crown of a tree in an area where root disease is present, the more likely it is that the roots have been weakened by decay.

Dense stands adjacent to the campgrounds would also benefit from thinning. Trees should be thinned to a basal area appropriate for the site in order to improve stand health and vigor. To reduce the susceptibility to future bark beetle related mortality, stands should be thinned to densities that are 80% or less of normal basal area, effectively reducing tree competition for

limited water and nutrients. Recent direction from the Regional Forester suggests designing thinnings to "ensure that density does not exceed an upper limit (for example: 90% of normal basal area, or 60% of maximum stand density index); this is a prudent way to avoid the health risks associated with density. Design thinnings to ensure that this level will not be reached again for at least 20 years after thinning." (Regional Forester letter, "Conifer Forest Density Management for Multiple Objectives", July 14, 2004). When implementing thinning projects, selecting for more drought tolerant species such as ponderosa pine and incense cedar over white fir will increase species diversity and make the stand more resilient to disturbance agents such as insects, disease, and fire. Thinning can also decrease the need to enter stands to conduct salvage operations, decrease the amount of fuel loading and reduce the number of hazard trees.

When planning such thinning, it should be recognized that this is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pine, as well as pure stands of younger ponderosa and pine should benefit by having the stocking around them reduced to lower levels. In addition to reducing tree stress, thinning, especially of the understory, will somewhat reduce the risks and damage from any fire that might occur and provide a more defensible space for the campground. At Cedar Pass, thinning could also help perpetuate riparian hardwoods such as willow and cottonwood thus replacing some of the stream shading and campground screening that might be lost by the removal of hazardous or understory conifers.

It is important to note that when implementing tree removal or hand thinning in a recreational site, it is Region 5 policy (FSM R5 Supplement 2300-92-1) to treat all conifer stumps with a registered borate compound to reduce the probability of infection by *H. annosum.* Care also needs to be taken to minimize both wounding of residuals and site disturbance. If regenerating any openings created during thinning and hazard tree removal is desired in the Cedar Pass campground planting ponderosa pine should be considered over natural regeneration of true fir, since this species is not a host for the fir strain of annosus root disease or fir dwarf mistletoe.

General Recommendations for Management Activities in Campgrounds

Maintaining and promoting healthy trees are important objectives for development plans in campgrounds. Care should be taken during future campsite, trail and facility construction to minimize negative impacts on the landscape. The following guidelines should be applied for areas under construction or in areas where future construction will take place.

- Tree density should be appropriate for the site. This will provide access to light, moisture and nutrients and allow the trees to better cope with their altered environment.
- Trees that will directly interfere with structures or that will be seriously damaged during construction or excavation should be removed.
- Leave a mixture of ages and species to provide a continual forest canopy over the years.
- Fence off individual or groups of trees before construction to negate or minimize root damage by soil compaction or trunk and root damage by equipment. Protective fences should be placed, at a minimum, at drip line. Depending on the species, tree roots can exist within a radius two times the crown radius and encompass an area well beyond drip

line. Drip line is defined by the outer edge of the foliage. Penalties for damaging trees should be incorporated into tree removal or construction contracts.

- Road or lot grades should be changed as little as possible. Grading damages roots and can set up conditions that favor soil erosion. It can also alter the contour such that the flow of surface and subsurface water is drastically affected.
- Trenches should always be dug away from tree roots.
- Do not back fill with earth or rocks around the trunks of trees.
- Avoid paving with either concrete or asphalt over root systems, or close to the trunks of trees.
- Use caution in applying wood preservatives and other chemicals to buildings. Trees and other plants have been killed by direct contact with them or as a result of their runoff in rainwater.
- Avoid leaving green pine slash on site to prevent the build up of pine engraver (*Ips pini*) beetle populations that may attack standing green trees.

Future construction or vegetation management activities that incorporate the above guidelines will help assure the existence of vigorous and healthy trees following project completion.

Recommendations for Hazard Tree Management

Despite the effectiveness of any long or short-term plans to prevent tree injury and mortality, some trees, through declining health, will eventually become hazards to the public. To minimize the risks associated with hazard trees, they should be identified and removed before they fail. Removing trees as they die eliminates the risk from dead trees but fails to address living trees that are infected with root disease, heart rot, and/or have a structural defect. These high-risk green trees are equally hazardous and should not be overlooked. Therefore, it is recommended that the Forest develop a hazard tree evaluation and monitoring plan for its campgrounds. At your request, Forest Health Protection can provided information and assist with the development of this plan. In the short-term, trees within the campground that have obvious stem decay, dead tops and/or large dead branches should be carefully evaluated and hazards removed or pruned as soon as possible.

The NE California Shared Services Area has access to a Resistograph. This tool is able to detect decay in trees by probing discrete points on the bole. Since advanced decay can exist anywhere in a tree it is often necessary to probe suspected areas of decay at many locations on the bole in order to be reasonably sure that a tree is sound. The Resistograph is most useful in determining the amount of sound wood in trees where advance decay is suspected in boles or branches after completing thorough visual examinations. It is also useful in locating the size and extent of internal defects, such as cracks. If you would like to schedule time to have suspected hazard trees examined with the Resistograph, please contact Bill Woodruff at 252-6680.

To facilitate a hazard tree evaluation plan, two copies of USDA Forest Service publication: Long-Range Planning for Developed Sites in the Pacific Northwest: The Context of Hazard Tree Management will be mailed to the appropriate District personnel.

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Conclusion

Any future management activities within the Blue Lake and Cedar Pass campgrounds should incorporate a long-term vegetation management plan that includes a hazard tree evaluation and monitoring plan. The recommendations provided in this evaluation combined with input from the District and/or Forest silviculturist will help insure the continued presence of healthy trees that will provide shade, campsite screening and visual/aesthetic qualities for these recreation areas.

Forest Health Protection may be able to assist with the emergency funding for a preventative spray project, including NEPA documentation, to protect high value trees in the Blue Lake and Cedar Pass campgrounds in FY05. This type of funding is granted based on availability and regional priorities. Forest Health Protection can also assist with funding for thinning and removing green material from overstocked areas and for treating dwarf mistletoe infected stands, including the pruning of infected limbs, within and adjacent to the on a competitive basis. If you are interested in this funding please contact any of the Forest Health Protection entomology staff for assistance in developing and submitting a proposal. The deadline for submitting proposals for FY06 funding is September 30, 2005.

If you have any questions regarding this report and/or need additional information please contact us at 530-251-2151

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Western pine beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensively studied and has proven to be an important factor in the ecology and management of ponderosa pine throughout the range of this host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. The pitch tubes are red-brown masses of resin and boring dust. Relatively few, widely scattered, white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheromones released during a successful attack attract other western pine beetles. Attacking beetles may spill over into nearby apparently healthy trees and overwhelm them by sheer numbers.

Life Stages and Development

These beetles pass through the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily upon temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem and then mine into the middle bark where they complete most of their development. Blue stain fungi, introduced during successful attacks, contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions Affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the West since 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles. Information from surveys initiated in the 1930s indicates that there were enormous losses attributed to western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size through successive beetle generations as is typical with Jeffrey pine beetle. Rather, observations indicate that emerging beetles tend to leave the group kill to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing outbreaks. When healthy trees undergo a sudden and severe moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant amounts of resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin flow to resist attack. Any condition that results in excessive demand for moisture, such as tree crowding, competing vegetation or protracted drought periods; or any condition that reduces that ability of the roots to supply water to the tree, such as mechanical damage, root disease, or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers and predaceous beetles are natural control agents when beetle populations are low.

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

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Annosus Root Disease

Heterobasidion annosum is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Annosus root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of *H. annosum* have major differences in host specificity. All isolates of *H. annosum* from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita have, to date, been of the 'P' group. Isolates from true fir and giant sequoia have been of the "S" group. This host specificity is not apparent in isolates from stumps; with the 'S' group being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

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Black Stain Root Disease

Black stain root disease is caused by the fungus *Leptographium wageneri* (asexual state *Verticicladiella wageneri*). In California, the fungus has three host-specific strains that infect either ponderosa and Jeffrey pine, singleleaf pinyon pine, or Douglas-fir. In most situations, the fungus does not cross-over between species, even in mixed species stands.

Initiation of disease centers probably occurs when spore-carrying, cambium feeding beetles invade tree roots and transmit the spores of the fungus to the tree. The fungus then grows in the wood of the root toward the root collar.

Once the fungus becomes established in a tree, it spreads locally between trees through rootlet contact or fungus growth through the soil for short distances and direct infection of small feeder roots. The rate of underground spread in a ponderosa pine stand is highly variable and dependent on species composition, stand density, and site.

The disease can be identified in a tree by the dark brown to black stain of the wood. This stain occurs as arcs that follow the annual rings. The amount of stain around the bole varies among trees. It may involve only a small part of the tree's circumference or it may encircle the tree. The stain may be one to many annual rings deep.

Infected trees undergo gradual to rapid crown decline prior to mortality. Symptoms of crown decline include reduced terminal growth, needle yellowing and shortening, and premature loss of foliage. Trees pole-size and larger may also bear a heavy cone crop. Bark and engraver beetles can successfully attack and kill infected trees. Douglas-firs may have grayish-blue resin streaming from the bark above the stained area.

Stands that are most likely to be damaged by black stain root disease (high-risk stands) are generally cooler, wetter sites which have a high percentage of ponderosa or Jeffrey pine in the overstory, are over-stocked, and have a history of site disturbance.